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PHENOLOGY OF PANDORA MOTH (LEPIDOPTERA: SATURNIIDAE) ADULT EMERGENCE AND EGG ECLOSION IN CENTRAL OREGON

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Abstract.—Pandora moth, *Coloradia pandora* Blake, adult emergence and egg eclosion were monitored at three sites in central Oregon. Accumulated degree-days above a threshold of 5° C from the beginning of adult emergence to the end of adult emergence were between 386.0 ± 7.8 and 459.3 ± 10.8, and from the beginning of adult emergence to the end of egg eclosion were between 648.7 ± 17.9 and 685.3 ± 21.1.

Key Words.—Insecta, *Coloradia pandora,* phenology, degree-days, adult emergence, egg eclosion

The pandora moth, *Coloradia pandora* Blake, is a defoliator of ponderosa, lodgepole, and Jeffrey pines (*Pinus ponderosa* Dougl. ex Laws., *Pinus contorta* Dougl. ex Loud., and *Pinus jeffreyi* Grev. & Balf., respectively) in the western United States (Carolin & Knopf 1968, Furniss & Carolin 1977). Most pandora moths have a two-year life cycle. Adults emerge, mate, and oviposit in mid-summer. Eggs hatch in late-summer and the young larvae feed in groups on needles near branch tips. The larvae overwinter on the branches and continue feeding the following spring. Most defoliation occurs in the spring prior to host shoot elongation. The mature larvae crawl down the bole in early-summer to pupate in the soil and litter. The pupal stage typically lasts about 12 months, although a small percentage of the population remains in the pupal stage for two to five years (Carolin 1971).

The pandora moth is normally inconspicuous, but periodic outbreaks have severely defoliated pines in parts of Oregon, Colorado, and Arizona (Patterson 1929, Wygant 1941, Schmid & Bennett 1988). Because defoliation occurs in alternate years and the larvae do not feed on the current years needles, tree mortality is minimal and usually associated with stressed trees (Wagner & Mathiasen 1985, Bennett et al. 1987). However, defoliation can cause significant growth loss and may predispose trees to bark beetle infestations (Patterson 1929, Miller & Wagner 1989). The large number and size of caterpillars and moths and the dramatic appearance of completely defoliated stands can be a considerable nuisance to property owners and recreationists within infested areas. The collapse of outbreak populations after three or four generations has usually been attributed to a naturally occurring virus.

Knowledge of pandora moth phenology is potentially useful for research and management applications. Published records of pandora moth phenology are based upon calendar dates that can vary considerably among generations depending upon weather conditions. This paper reports phenological observations of pandora moth adult emergence and egg eclosion based upon heat accumulations from the beginning of moth flight.

Methods and Materials

Pandora moth phenology was monitored at three sites on the Fort Rock Ranger District of the Deschutes National Forest about 20 km S of Bend, Oregon. The three sites were within 2.5 km of one another. Plant associations for the study sites were ponderosa pine/bitterbrush/fescue and ponderosa pine/bitterbrush-manzanita/fescue (Volland 1985). Elevations were 1400–1440 m, aspects were S to SW, and slopes were 0–5%. Ponderosa pine was the only tree species present on the plots. At the time of the study, tree age (mean ± SE) was 62 ± 2 years, diameter at breast height was 18.4 ± 2.0 cm, height was 11.7 ± 1.9 m, and basal area was 37.4 ± 6.2 m^2/ha.

These stands were moderately to heavily defoliated by the pandora moth in 1990 (USDA Forest Service 1990). Between 28 May and 5 Jun 1991, 25 cages (34 × 47 cm) were staked to the ground at 5 × 5 m spacings at each site to monitor adult emergence. The cages were inspected on 16, 17, 22, and 30 Jul; 4, 8, 13, 19, and 27 Aug; and 9 Sep 1990. The number and sex of moths present on each visit were recorded. For each date, adult emergence was calculated as a percentage of the total seasonal emergence.

Pandora moth eggs and larvae were sampled on 14 and 29 Aug and 10, 17, and 24 Sep 1991. On each date, 10 randomly selected dominant or codominant trees were sampled at each site. One 30–45 cm long branch tip was removed with a pole pruner from the mid-crown on both the N and S sides of each tree. The branches were taken to the laboratory and eggs and larvae present were counted. Percent egg hatch was calculated as the number of larvae divided by the number of larvae plus the number of unhatched eggs.

At the time that emergence cages were installed, an electronic data recorder with two temperature sensors (Omnidata Datapod® model DP-212, Logan, Utah) was placed at each site. The temperature sensors were placed in partially shaded locations within the crowns of understory trees about 1–2 m above the ground. The instrument scanned temperatures at 5 min intervals and recorded daily maximum and minimum temperatures. Degree-days were calculated from the temperature data by the modified sine wave method (Allen 1976) beginning on 17 Jul when the first adults emerged in the plots. A lower threshold of 5° C was arbitrarily chosen for degree-day calculations because developmental thresholds for the pandora moth were unknown. However, temperatures below 5° C interrupt incubation of pupae and eggs of closely related bombycid and saturnid moths (Rivnay & Sobrio 1967, Wang 1989), and the lower developmental thresholds for eggs of other North American forest defoliators are near 5° C (Wickman 1976).

Results and Discussion

The first adult moths were observed in Bend, Oregon on 12 Jul (R. G. Mitchell, personal communication) and in La Pine, Oregon (about 20 km S of the study sites) on 16 Jul (unpublished data). Emergence holes in the soil surface and adult moths were first observed on the plots on 17 Jul, although no adults were captured in emergence traps until 4 Aug.

The last adult moths were collected from the emergence traps on 27 Aug when the mean degree-day accumulation (± SE) was 459.3 ± 10.8 (Fig. 1). Those moths could have emerged on or after 20 Aug, the day following the previous collection, when the mean degree-day accumulation was 386.0 ± 7.8 degree-days. The last

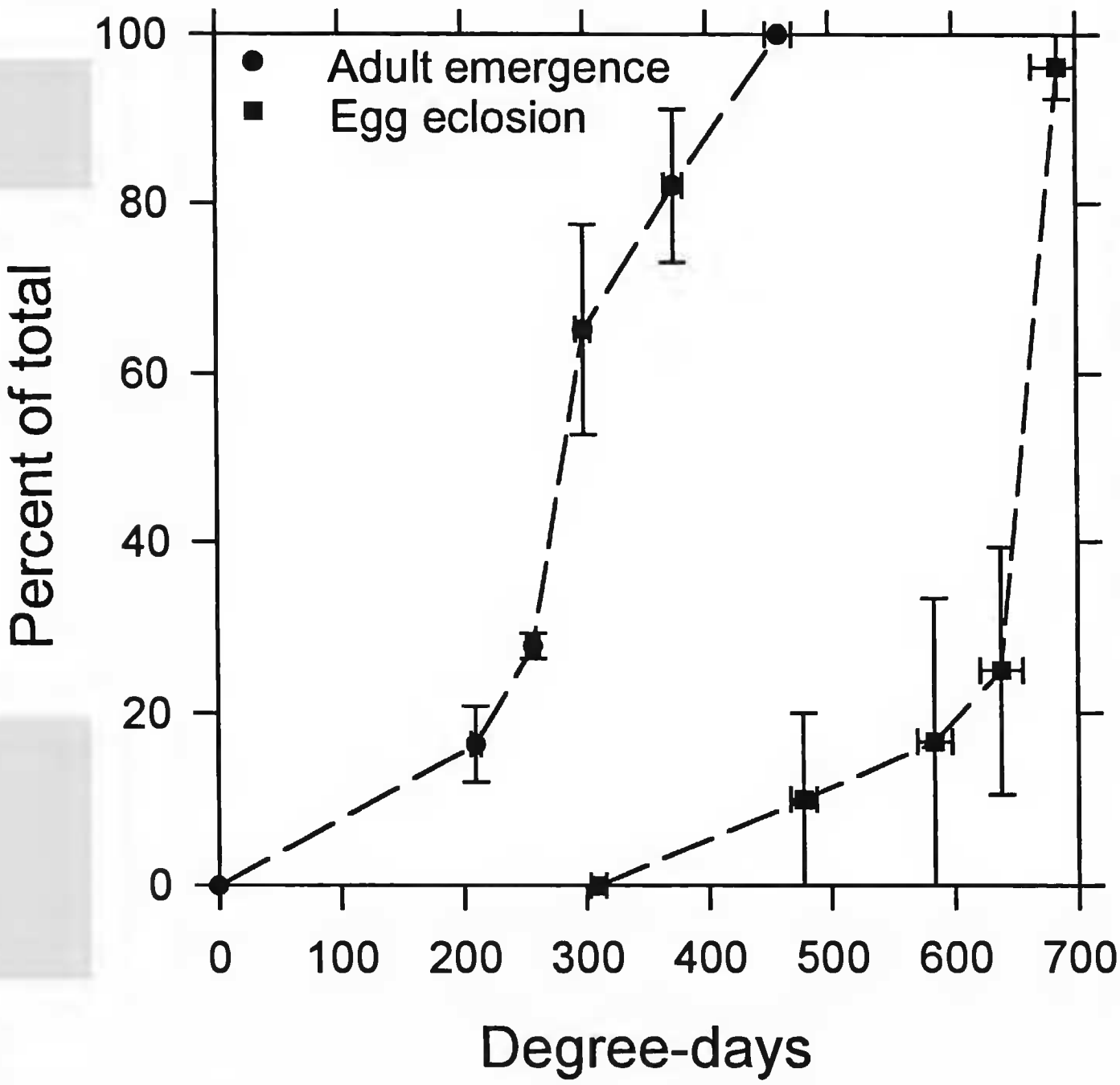

Figure 1. Percent pandora moth adult emergence and egg eclosion as a function of degree-days accumulated since the beginning of adult emergence in central Oregon, 1991. Bars indicate standard errors.

male moths were collected on 19 Aug when the mean degree-day accumulation was 373.0 ± 7.8 degree-days. Those moths could have emerged on or after 14 Aug, when the mean degree-day accumulation was 309.0 ± 6.1 degree-days.

Egg eclosion reached 96.2 ± 3.8% by 24 Sep when the mean degree-day accumulation was 685.3 ± 21.1 degree-days (Fig. 1). The last eggs could have hatched on 18 Sep, the day after the previous sample date, when the mean degree-day accumulation was 648.7 ± 17.9 degree-days. The few eggs that remained unhatched on the last sample date were likely infertile or unhealthy.

Degree-day accumulations can be used to estimate the end of adult emergence, egg eclosion, or to time control activities. For example, a fall application of a non-persistent insecticide will be most effective if it is applied soon after all eggs have hatched (Ragenovich et al. 1986). This date could be determined by repeatedly sampling foliage for the presence of eggs and larvae. Alternatively, the date could be estimated by accumulating degree-days from the date adult emergence begins until a total of 649 is reached. These degree-day accumulations should

be used only in central Oregon until they are verified in other parts of the geographic range of the pandora moth.

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